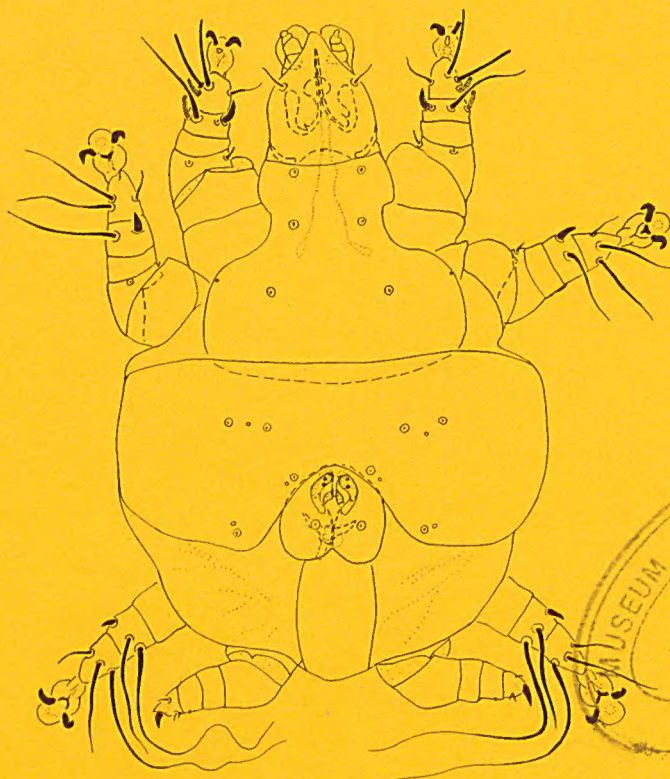


THE AUSTRALIAN Entomologist

published by
THE ENTOMOLOGICAL SOCIETY OF QUEENSLAND



Volume 34, Part 1, 1 March 2007

Price: \$6.00 per part

ISSN 1320 6133

THE AUSTRALIAN ENTOMOLOGIST

ABN#: 15 875 103 670

The Australian Entomologist is a non-profit journal published in four parts annually by the Entomological Society of Queensland and is devoted to entomology of the Australian Region, including New Zealand, Papua New Guinea and islands of the south-western Pacific. Articles are accepted from amateur and professional entomologists. The journal is produced independently and subscription to the journal is not included with membership of the society.

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Cover: *Parobia alipilus* Seeman & Nahrung (Podapolipidae) is one of three sexually-transmitted mites that infest the eucalyptus leaf beetle *Paropsis atomaria*. The adult male (pictured) is unlike the female: his legs have spurs, the genital capsule is mid-dorsal and the fourth pair of legs is modified. Nevertheless, *Parobia* species are among the most mite-like of the Podapolipidae, where physogastry and loss of legs is common and some males have their genitalia on prongs above their heads. *Parobia* mites are often more common on female beetles and at least one species significantly reduces survival of the host during overwintering. Illustration by Owen Seeman.

A NEW SPECIES OF *GUDANGA* DISTANT (HEMIPTERA: CICADIDAE) FROM NORTHERN QUEENSLAND

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Abstract

Gudanga pterolongata sp. n. is described and illustrated from northwestern Queensland. Specimens were collected in open woodland between Georgetown and Croydon, during the months of January and February, from 1996 to 2005.

Introduction

The Australian cicada genus *Gudanga* Distant was reviewed by Moulds (1996), who described four new species, bringing the total to six species in the genus. A key was also provided by Moulds (1996). In this paper, a further species is described from northwestern Queensland and relevant adjustments are made to the existing key.

Terminology follows that of Moulds (2005). The following abbreviations are used: AMS - Australian Museum, Sydney; JO - author's collection; MDL - collection of M.D. Lane; MSM - collection of M.S. Moulds; SL - collection of S. Lamond.

Key to species

- 1 Abdominal tergites 1-6 black (entirely lacking areas of orange pigmentation) 6
 - Abdominal tergites 1-6 with obvious areas of orange pigmentation 2
- 2 Hind wing hyaline, orange at base 3
 - Hind wing entirely orange or red basally, remainder fuscous as on forewing 5
- 3 Orange pigmentation covering basal half of hind wing; remainder hyaline. Anal lobe orange with outer half fuscous as on forewing (northwestern Qld) *pterolongata* sp. n.
 - Hind wing without fuscous area 4
- 4 Hind wing with orange suffusion extending beyond anal lobe, the orange beyond lobe mainly along costa [take care not to confuse this area with the orange forewing basal membrane] (southern Qld) *adamsi* Moulds
 - Hind wing with orange confined to anal lobe, almost entirely to the plaga and the area between the plaga and inner margin (southern WA) *kalgoorliensis* Moulds
- 5 Pigmentation of hind wing apical cells 1-5 paler than forewing and showing slight orange suffusion {clearly visible when specimen is held approximately 10 cm above a white background}; abdomen of male in dorsal view nearly parallel-sided for much of its length (southwestern WA) *aurea* Moulds

- Pigmentation of hind wing apical cells 1-5 similar to that of forewing; abdomen of male in dorsal view tapering from base to apex (southern WA) *browni* Distant
- 6 Base of hind wing crimson; remainder of hind wing usually hyaline but sometimes fuscous (southwestern WA) *boulayi* Distant
- Base of hind wing reddish-orange; remainder of hind wing always fuscous, never hyaline (southwestern WA) *solata* Moulds

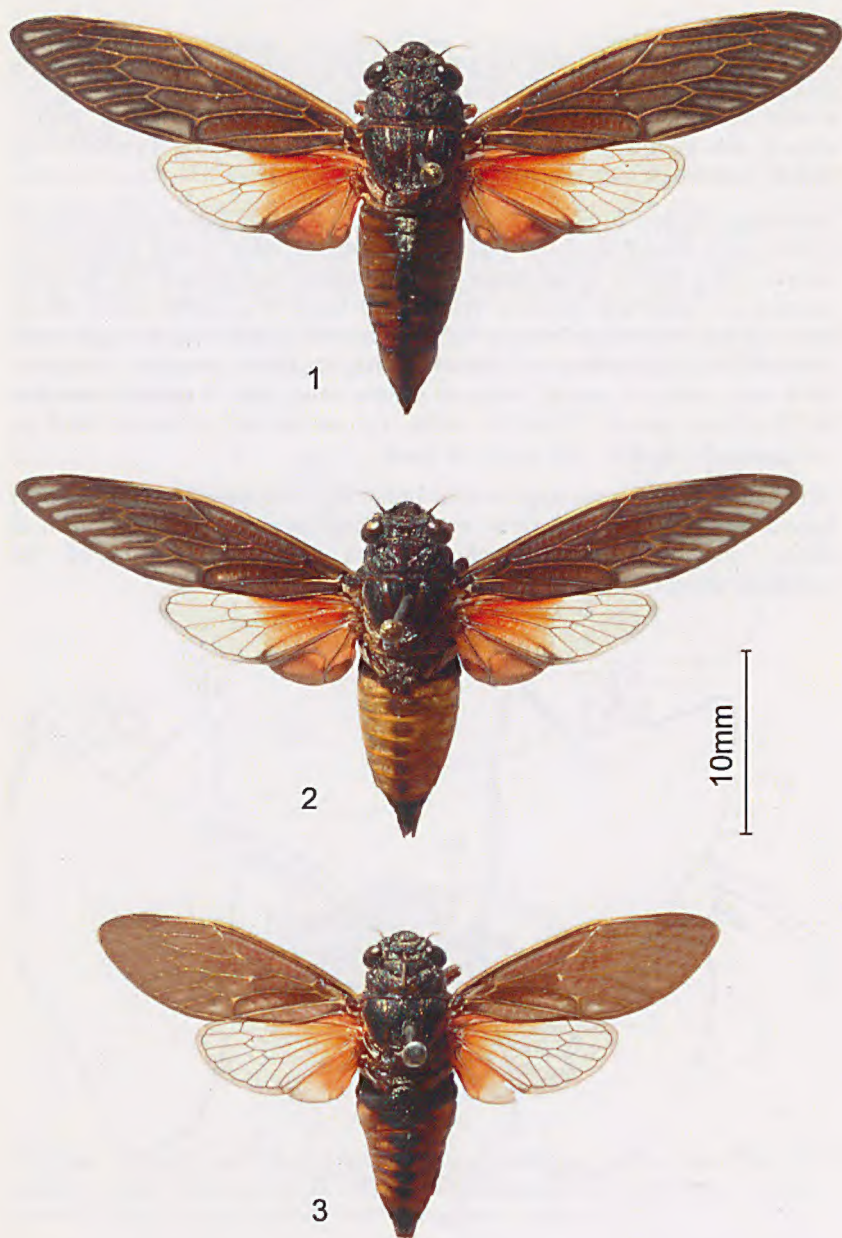
***Gudanga pterolongata* sp. n.**

(Figs 1-2, 4, 7-8)

Types. *Holotype* ♂, QUEENSLAND: Venture Ck, 81 km W Georgetown, 18°13'22"S, 142°48'37"E, 8.ii.2004, J. Olive & J. Thompson (AMS: Reg. No. K225456). *Paratypes*: 4 ♂♂, 1 ♀, Venture Ck, 80 km W Georgetown, 18°13.379'S, 142°48.716'E, 19.i.2005, Hill, Marshall, Moulds (MSM); 1 ♂, Marsupial Ck, E Croydon, 2.ii.2002, J. Hasenpusch (MSM); 2 ♂♂, 76 km W Georgetown, 19.ii.2005, J. Olive & J. Thompson (MDL), 13 ♂♂, 76 km W Georgetown, 19.ii.2005, J. Olive & J. Thompson (JO), 4 ♂♂, Venture Ck, 81 km W Georgetown, 18°13'22"S, 142°48'37"E, 8.ii.2004, J. Olive & J. Thompson (JO); 1 ♂, Croydon, 30.i.[19]96, S. Lamond (SL); 1 ♂, Croydon, 1.ii.[19]96, S. Lamond (SL).

Description. Male (Fig. 2). Head black or brown; a triangular cream mark on midline, extending from between the lateral ocelli to the posterior margin; ocelli reddish-amber; postclypeus brown with cream margin, transverse ridges prominent and moderately covered with white cilia, midline groove becomes wider and deeper anteriorly, dorsal surface tending paler posteriorly, sometimes with anterior pale patch at midline; anteclypeus dark brown; lorum dark brown to black with cream outer margin; rostrum just reaching bases of hind coxae, brown becoming black distally; antenna dark brown basally, gradually becoming lighter apically, apical segments sometimes dark brown to black.

Thorax: pronotum brown with anterior margin cream; midline with a broad dark brown to black fascia along its length, expanded laterally at either end; lateral and paramedian fissures black, with a variable amount of black colouration in adjacent areas; pronotal collar brown with light brown posterior margin and light brown anterior margin in dorsal region. Mesonotum dark brown; submedian sigilla distinct, completely black or brown; lateral sigilla completely black or brown, the black pigmentation extending to the anterior arms of cruciform elevation; midline often light brown; scutal depressions black. Legs brown; femur with longitudinal darker markings. Forewings long and narrow, with length to width ratio 3.3:1; opaque brown-black, more heavily pigmented adjacent to veins; apical cells usually translucent; veins yellow-orange except for cream costa; basal membrane light orange; length greater than body length. Hind wings with basal half, or a little less, deep translucent orange, remainder hyaline; anal lobe light orange, brown-black distally; under magnification distal area

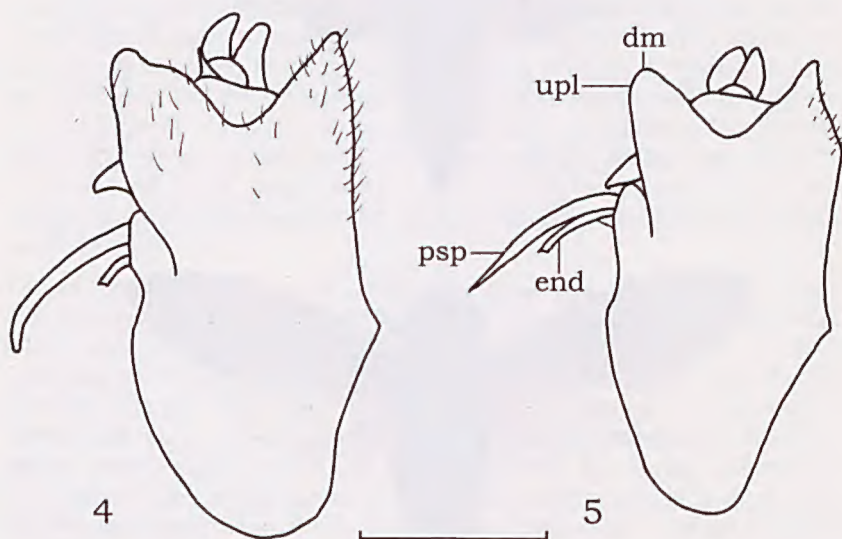


Figs 1-3. *Gudanga* spp. (1) *G. pterolongata* sp. n., female; (2) *G. pterolongata* sp. n., male; (3) *G. adamsi* Moulds. Scale applies to all specimens.

appears embossed with inner margin of this raised area highlighted by a thin, dark line; the fuscous colouration is usually tinged orange and does not always extend to inner margin. Opercula (Fig. 7) long and narrow, paddle shaped; pale yellow, basal swelling and adjacent area brown. Tymbals (Fig. 8) with four long ribs and one short dorsal rib.

Abdomen: tergite 1 brown with anterior margin finely edged orange; tergite 2 yellow with broad brown dorsal patch, anterior edge black; tergites 3-7 yellow with a brown dorsal patch that is broadest on tergite 3, the posterior margins are generally brighter yellow and there is a brown patch at the lateroventral extremities; tergite 8 dark brown to black with approximately anterior third yellow. Sternite I brown to muddy yellow; sternite II brown or black with posterior margin cream to yellow either side of midline; sternites III-VI yellow; sternite VII darker yellow on anterior half, brown or black on posterior half; sternite VIII brown or black.

Genitalia (Fig. 4). Upper pygofer lobe broad with mid-dorsal margin strongly curved outward in lateral view; pseudoparameres apically down-turned in lateral view; endotheca reaching about half the length of the pseudoparameres.

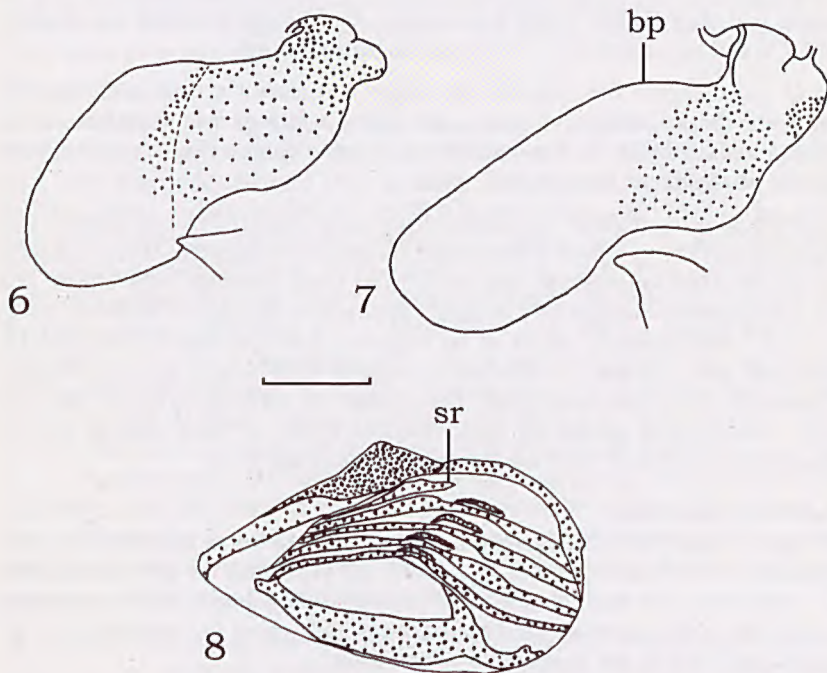


Figs 4-5. *Gudanga* spp., lateral view of male genitalia - dm = dorsal margin, end = endotheca, psp = pseudoparameres, upl = upper lobe of pygofer. (4) *G. pterolongata* sp. n.; (5) *G. adamsi* Moulds. Scale line approx. 1 mm.

Female (Fig. 1). Similar to male except abdomen slightly darker in colour. Ventral surface of abdomen with a broad, black midline. Abdominal segment 9 with dorsal beak and adjacent area black. Ovipositor sheath reddish-brown with apex black; extending just beyond tergite 9.

Measurements. All available specimens were measured. The range and mean (in mm) for 27 males and one female are: Body length - male 16.75-20.5 (18.8), female 19.8; forewing length - male 17.0-20.5 (19), female 20.5; forewing width - male 5.1-6.25 (5.7), female 6.0; head width - male 4.75-5.5 (4.8), female 5.25; pronotum width - male 5.2-6.6 (5.8), female 6.4.

Etymology. Derived from the Greek *pteron*, meaning wing, and the Latin *elongatus*, meaning much longer than wide, being descriptive of the long, narrow forewing.



Figs 6-8. *Gudanga* spp. - bp = basal portion of outer margin, sr = short rib. (6) *G. adamsi* Moulds, right opercula; (7) *G. pterolongata* sp. n., right opercula; (8) *G. pterolongata* sp. n., right tymbal. Scale line approx. 1 mm.

Comments. *Gudanga pterolongata* more closely resembles *G. adamsi* (Fig. 3) that the other described species in the genus. The forewing of *G. pterolongata*, although approximately the same width as in *G. adamsi*, is

considerably longer, being greater than the total body length; the length to width ratio is 3.3:1. In *G. adamsi* the forewing length is less than its body length, with a length to width ratio of 2.5:1. The orange pigmentation on the hind wing of *G. pterolongata* covers approximately the basal half, whereas in *G. adamsi* this colouration is restricted to less than the basal third, including the plagal area. *G. pterolongata* has an area of brown-black pigmentation, similar to that of the forewing on the distal half or so of the anal lobe, that is not present in *G. adamsi*.

There are a few genitalic differences between *G. pterolongata* and *G. adamsi* (Figs 4-5). In lateral view, the upper pygofer lobe is broader in *G. pterolongata*, with the dorsal margin strongly curved outwards compared with the slight curvature in *G. adamsi*. In *G. pterolongata* the pseudoparameres are apically down-turned, with the endotheca reaching to about half their length, while in *G. adamsi* the pseudoparameres are apically straight and the endotheca is more than half their length.

In *G. pterolongata* the opercula are longer and narrower than in *G. adamsi*, with the basal portion of the outer margin being much shorter in *G. pterolongata* (Figs 6-7). The tymbals of *G. pterolongata* (Fig. 8) have a short dorsal rib that is not present in *G. adamsi*.

Distribution and habitat. Specimens have been collected in late January and throughout February from a few locations between Georgetown and Croyden in northwestern Queensland, appearing to be most abundant from 75 km west of Georgetown through to Croydon. Specimens labelled 'Croydon' by S. Lamond were actually taken at an unknown location east of Croyden (S. Lamond, pers. comm.). Adults are associated with *Acacia shirleyi* Maiden, commonly known as lancewood. The cicadas are difficult to find as they are well camouflaged against the dark coloured trunks of these acacias and are most abundant where there are larger groups of these trees.

Acknowledgements

I wish to thank M.S. Moulds and S. Lamond for access to specimens in their collections. I am also grateful to J. Booij for providing the photographs and G. Sankowsky for plant identification. For the many days and hours assisting me in the field, preparing the line drawings and typing the manuscript, I am deeply indebted to my partner Judy Thompson.

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ORIENTAL AND PACIFIC THIRIPIDAE (THYSANOPTERA) NEW TO AUSTRALIA, WITH A NEW SPECIES OF *PSEUDODENDROTHRIPS* SCHMUTZ

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Abstract

Nine species of Thripidae not yet, or only recently, listed from Australia are recorded from Queensland, with *Pseudodendrothrips alexei* described as new. Seven of these species are known from tropical areas to the north of Australia [*Anaphothrips swezeyi* Moulton; *Bathrips melanicornis* (Shumsher); *Caprithrips orientalis* Bhatti; *Craspedothrips minor* (Bagnall); *Danothrips trifasciatus* Sakimura; *Mycterothrips nilgiriensis* (Ananthakrishnan); *Scolothrips asura* Ramakrishna & Margabandhu]. The other two have been collected on plant species also found in Asia [*Mycterothrips desleyae* Masumoto & Okajima; *Pseudodendrothrips alexei* sp. n.]. These records further emphasise the difficulties of distinguishing between native and invasive thrips species in the northern Australian fauna.

Introduction

The number of Thysanoptera species recognised in Australia has increased considerably in recent years. Prior to 1915 fewer than 20 Australian species had been described (Mound 1996), but the number had increased to 287 by 1970 (CSIRO 1970), to 400 by 1974 (CSIRO 1974), and to 445 by 1996 (Mound 1996). In 2006 the total number of species listed on the Australian Biological Resources Study (2006) web site was 700. Most are Australian endemics, although about 10% of them are introduced from other countries. In this paper our objectives are to record from Australia six further Thripidae that either have been imported inadvertently on living plants or are natural immigrants into northern Australia. In addition, two endemic species are discussed that we have collected recently near Brisbane. Both are from plant species that have distributions into Asia. One, *Pseudodendrothrips alexei* sp. n., is described here; the second, *Mycterothrips desleyae*, was described by Masumoto and Okajima (2006), together with the first Australian record of the congeneric *M. nilgiriensis* (Ananthakrishnan). The presence of these nine species further emphasises the difficulties of distinguishing between invasive and native thrips species in northern Australia.

In southern Australia, introduced species are usually readily distinguished from the native fauna, particularly because of their association with non-native plants, but in the northern tropical zone this distinction is less easy. Not only are many plant species in northern Australia shared with Asia, but many thrips species are potentially wind-dispersed immigrants from Indonesia (Mound 2004). For all nine species discussed here bibliographic and synonymic details are available in the Checklist of World Thysanoptera (Mound 2005). Voucher specimens are in the Australian National Insect Collection [ANIC], Canberra, and Queensland Department of Primary Industries Collection [QDPI], Indooroopilly, except where indicated.

***Anaphothrips swezeyi* Moulton**

Described from Hawaii on sugar cane (Moulton 1928), this species is otherwise recorded only from New Caledonia, where it was collected on roadside grasses (Bournier and Mound 2000). Recently, both sexes have been collected in eastern Queensland, on grasses at several sites: Cape Tribulation (vii.1995), Sherwood, Brisbane (iii.2002), Port Douglas (viii.2004). It is a typical member of the genus with no long setae on the pronotum, and can be recognised by the following characteristics: body clear yellow; antennae 8-segmented with segments I-II yellow, III-IV light brown and V-VIII brown; ocellar setae III arising outside the ocellar triangle; metanotum with transverse reticulation, campaniform sensilla absent; abdominal tergite VIII with a posteromarginal comb of long uniform microtrichia.

***Bathrips melanicornis* (Shumsher)**

Described from India (Shumsher 1946), this species is also recorded from Myanmar, Java, Malaya and Taiwan (Bhatti 1990). Moreover, specimens are available [in ANIC] from Bali, Thailand and East Timor. Collections from Thailand suggest that this thrips is associated with the leaves of vegetable crops, including potatoes. In Australia, a few females have been collected at several sites in eastern Queensland and northern New South Wales: Cape Tribulation (vii.1995), Mareeba (i.1998), Mt Glorious, Brisbane (iii.2002), south of Lamington N.P. (vii.2002). The body colour is distinctive: abdomen yellow but each tergite with a large dark mark medially; forewings and all antennal segments dark; head with a pair of long setae between the posterior ocelli, but without a pair of setae in front of the first ocellus; pronotum with two pairs of long posteroangular setae; metanotum with no sculpture medially, median setae arise behind anterior margin and campaniform sensilla absent; tergite VIII with no posteromarginal comb.

***Caprithrips orientalis* Bhatti**

Described from central India (Bhatti 1973), this minute apterous grass-living species has been recorded subsequently from Fiji (Mound and Walker 1987) and New Caledonia (Bournier and Mound 2000). Two females were collected on grasses at two separate sites in eastern Queensland during July, 1995: 15 km south of Charters Towers and just south of Townsville. This is the third member of this genus recorded from Australia; *C. moundsi* Bhatti is common in the tussocks of native *Poa* species in southern Australia, whereas *C. insularis* Beshear from Trinidad and Surinam was recorded in Australia from one female collected just south of Brisbane. In publishing this record, Bhatti (1980a) provided an identification key to these species.

***Craspedothrips minor* (Bagnall)**

Described from southern India (Bagnall 1921), this species has also been described, under other names, from Indonesia and Taiwan (Bhatti 1990). Little information is available on its biology, although specimens have been

studied from *Cassia* taken at New Delhi. From Australia the following specimens have been studied: Western Australia, Broome, two females from *Solanum melongena* (iv.1999); New South Wales, 30 km west of Nelligen, one female from *Lomandra longifolia* flowers (x.2000); Queensland, Rockhampton, eight females from *Plumbago zeylonica* flowers (xi.2005). Members of this genus of Thripidae are distinguished by the presence of two exceptionally stout sensoria on the inner and outer margins of antennal segment V, plus one similar one on the external margin of segment VI. The body of *C. minor* is brown, with brown forewings and antennae, and the species has the following character states: head with a pair of small setae in front of first ocellus, ocellar setae III long and arising within ocellar triangle; antennal segment IV with slender neck-like apex; metanotum with weak sculpture medially, median setae almost at anterior margin, campaniform sensilla present; sternites and tergites (including VIII) with narrow marginal craspedum.

***Danothrips trifasciatus* Sakimura**

Described from Hawaii (Sakimura 1975) as causing damage to *Anthurium* plants, this species is recorded as producing spots on the skin of red grapefruit (*Citrus*) in Florida (Childers 1997). Moreover, Bhatti (1980b) recorded it as damaging banana fruit in the Caribbean, and also recorded it from Sumatra. In Australia the species is known from a single female, taken from a succulent plant in a suburban garden at Sherwood, Brisbane (xii.2002). This is a yellow species with slender forewings that bear three shaded cross-bands, at base, middle and near apex. The structural features are: head and pronotum with almost no sculpture, no setae in front of first ocellus; metanotal median setae far from anterior margin; median tergites with transverse sculpture lines medially; tergite VIII with no posteromarginal comb of microtrichia.

***Mycterothrips desleyae* Masumoto & Okajima**

The genus *Mycterothrips* Trybom was recorded recently from Australia during a revision of the world species (Masumoto and Okajima 2006). The two species found in Australia share the following characters: head with pair of setae in front of first ocellus, ocellar setae III long and arising within ocellar triangle; antennae 8-segmented, segment I with a pair of dorso-apical setae; setal row on forewing first vein with long interval then 2 setae near wing apex; tergite VIII with conspicuous posteromarginal comb of long slender microtrichia. Moreover, the males of the two Australian species have remarkable antennae in which the sixth segment is greatly enlarged and bears numerous setae like a bottle brush. The second instar larvae are distinctive, with the major setae long but broadly capitate with coarsely fringed apices. *M. desleyae* was collected in substantial numbers, between October 2005 and January 2006, breeding on the leaves of several trees of *Clerodendrum floribundum* in Brisbane Forest Park. A few specimens were also taken from

the flowers and branches of these trees, and several specimens were collected from the same plant species at Cooloola National Park, north of Brisbane. The males of *M. desleyae* have antennal segment VI between 0.5 and 0.6 times as long as the combined lengths of segments I–V.

***Mycterothrips nilgiriensis* (Ananthakrishnan)**

Described from southern India (Ananthakrishnan 1960), this species has been recorded widely across India (Bhatti 1990) and from Nepal and Taiwan (Masumoto and Okajima 2006). The latter authors also identified two specimens from the ANIC as this species: Queensland, Mt. Glorious, one female, January 1988; and New South Wales, Wisemans Ferry, one female, April 1968. Subsequently, in October 2006, a long series of males, with two females and one second instar larva, were collected from the leaves of *Ficus coronata*, 15 km west of Mt Glorious, and a few males were also taken from the leaves of *Ricinus communis* at the same locality. The males have antennal segment VI more than 1.0 times as long as the combined lengths of segments I–V.

***Scolothrips asura* Ramakrishna & Margabandhu**

Described from India (Ramakrishna and Margabandhu 1931), and also known from Bangladesh and southern China (Bhatti 1960) as well as Taiwan (LAM collection), a single female of this distinctive species is preserved in the University of California Riverside Collection, collected at Gordonvale, northern Queensland, in January 1966. As in other species of the genus, all of which are predators on leaf-feeding mites, the forewings are transversely banded and the pronotum bears six pairs of exceptionally long setae. However, the body of *S. asura* is brightly coloured, with the legs, pronotum and abdominal segments IV–V white, the head, pterothorax and abdominal segments VI–VIII brown and with bright red internal pigment.

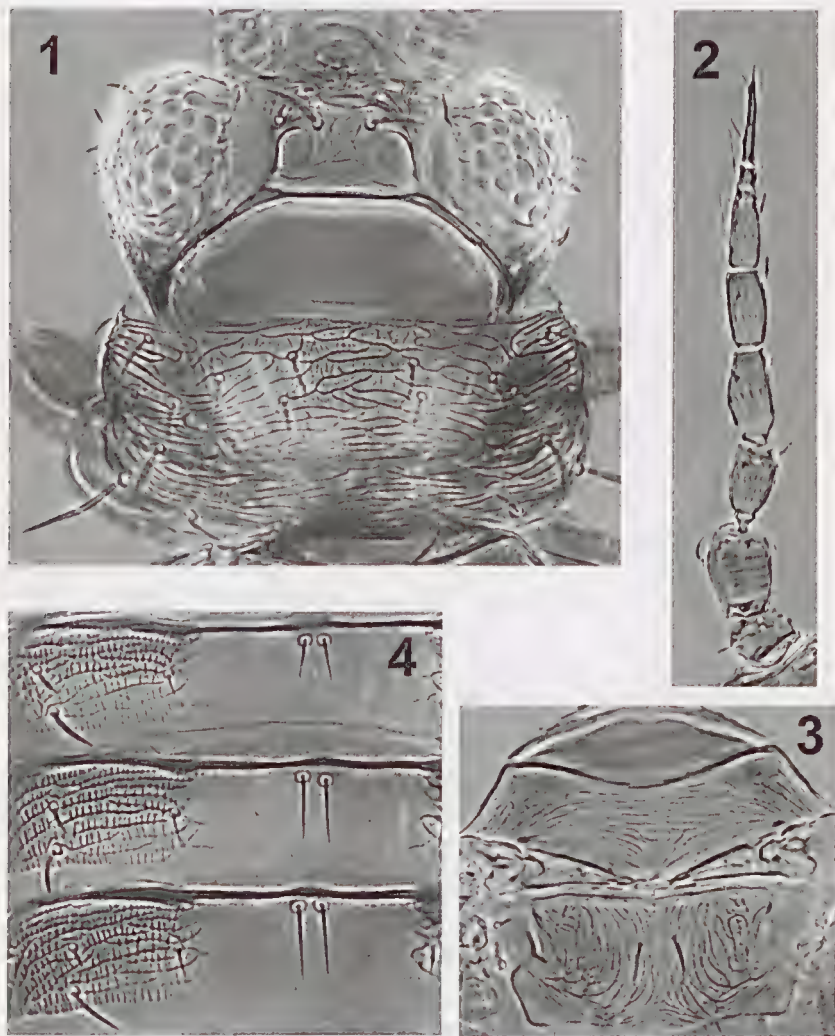
***Pseudodendrothrips alexei* sp. n.**

(Figs 1–4)

Types. Holotype ♀, QUEENSLAND: Brisbane Forest Park, from leaves of *Machura cochinchinensis* (Moraceae), 16.i.2006 (LAM 4815) (in ANIC, Canberra). *Paratypes:* 9 ♀♀ collected with holotype (in ANIC, Canberra, and QDPI, Indooroopilly).

Description. Female macropterous, body light brown to brown with extensive red internal pigment (in life appearing almost black); antennae light brown, segments IV–VI yellow in basal half; all tibiae yellow at base and apex; forewings uniformly shaded; compound eyes with 5 weakly pigmented facets. Head broader than long (Fig. 1), ocellar triangle finely sculptured, also area in front of ocelli; 3 pairs of ocellar setae present, pair I lateral to anterior margin of fore ocellus, pair III slightly fluted and arising between anterior margins of hind ocelli; maxillary palps 2-segmented. Antennae 8-segmented (Fig. 2); segment VI with major sensorium arising at a point about 25% of the segment length from the base. Pronotum transversely reticulate with

markings inside each reticle (Fig. 1); one pair of prominent posteroangular setae, 2 pairs of posteromarginals; all setae slightly fluted. Forewing first vein with 3 setae near base and 2 setae distally, ventrally with row of corpusculae (see Bhatti 1997); anteromarginal cilia arising slightly sub-marginally; clavus with apex rectangular bearing 2 veinal and 1 discal setae. Sculpture of mesonotum and metanotum (Fig. 3), also abdominal tergites (Fig. 4), typical of genus.



Figs 1-4. *Pseudodendrothrips alexei* sp. n.: (1) head and pronotum; (2) antenna; (3) mesonotum and metanotum; (4) abdominal tergites IV-VI.

Second instar larva white with three pairs of dark spots on pronotum, two pairs each on meso and metanotum, and two pairs in a transverse row on tergites II - VIII; spiracles on tergites II and VIII small, dorsal, surrounded by dark area; major setae minute with blunt apices.

Measurements. Holotype female in microns. Body length 750. Head, length 50; width across eyes 150; ocellar setae III length 20. Pronotum, length 65; width 150; posteroangular setae 35. Forewing length 530. Hind tibia length 85; hind tarsus length 50. Antennal segments III–VIII length 28, 25, 25, 25, 10, 35.

Comments. Members of the genus *Pseudodendrothrips* Schmutz can be recognised by the enlarged (lyre-shaped) metathoracic endofurca, the elongate hind tarsi that are more than half the length of the hind tibiae and the distinctive sculpture of the mesonotum and metanotum (Fig. 3). *P. alexei* sp. n. differs from all 16 previously known species in the long and slightly fluted interocellar setae. The forewings are uniformly light brown, a character state shared with one species from northern India, but the sensorium on the sixth antennal segment does not arise as close to the base as in the other members of this genus. The antennae are 8-segmented, but the suture between antennal segments VI and VII is oblique and variable amongst the available specimens, and is not present dorsally in the right antenna of the holotype. Because of this, when more extensive samples are examined individuals can be expected to occur in which the suture is not developed at all, and the antennae would thus have only seven visible segments.

Two South American species described in this genus (Hood 1952) are more properly placed in the related Neotropical genus *Halmathrips* Hood, as indicated by Mound and Marullo (1996). The remaining species are all from the Old World tropics and sub-tropics (Table 1), but no comprehensive account of these has been published. The sculpture of the metanotum and the abdominal tergites (Figs 3, 4) is remarkably constant among all of the known species, and these have been distinguished generally on slight colour differences and the number of antennal segments. The body colour of 13 species is described as various shades of white to yellow, sometimes with the head slightly darker around the bases of the antennae, and the forewings pale to slightly shaded. However, the identity of some of these pale species is uncertain (Mound 1999) and requires confirmation through a study of more extensive series to investigate variation within and between populations. Two described species are distinctive in having banded forewings, and one other species has the body and wings uniformly brown (Table 1).

The number of antennal segments, whether eight or nine, is used commonly to distinguish species in this genus, although subdivision of the terminal antennal segments is known to be variable in related species. The sixth antennal segment is sometimes subdivided producing an apparent 9-segmented antenna, alternatively this segment is not only undivided but is

fused to the seventh segment, thus producing a 7-segmented antenna. Within this genus, when a species is known from a good series of specimens it is not unusual to find that the number of antennal segments is unstable.

Table 1. World species of *Pseudodendrothrips* Schmutz. For synonymies and publication details see Mound (2005).

Species	Antennal segments	Localities
(i) Body white to yellow, head sometimes darker		
<i>aegyptiacus</i> Priesner, 1965.	8	Egypt; Canary Is.
<i>albana</i> Bhatti, 1997	9	India
<i>bhattii</i> Kudo, 1984	8/9	Japan; Australia
<i>candidus</i> zur Strassen, 1993	9	Cape Verde Is.
<i>ficus</i> Hartwig, 1948	9	South Africa
<i>darci</i> Girault, 1930	8/9	Australia
<i>mori</i> Niwa, 1908	8/9	Widespread
(ii) Body yellow, head brown		
<i>fumosus</i> Chen, 1980	9	Taiwan
<i>lateralis</i> Wang, 1993	9	Taiwan
<i>ornatissimus</i> Schmutz, 1913	9	Sri Lanka; India
<i>puerariae</i> Zhang & Tong, 1990	9	China
<i>suvarna</i> Bhatti, 1997	8/9	India
<i>ulmi</i> Zhang & Tong, 1980	9	China
(iii) Forewings with dark and light bands		
<i>gillespiei</i> Mound, 1999	9	Australia
<i>maculosus</i> Reyes, 1994	8	Philippines
(iv) Body and wings uniformly brown		
<i>kulshresthai</i> Chaunan & Vijay Veer, 1992	8	India
<i>alexei</i> sp. n.	8	Australia

Acknowledgements

We are grateful to Tony Postle of AQIS, Cairns, for sending thrips specimens that he had collected around Broome, and to Tong Xiao-Li of Guangzhou and Vijay Veer of Dehra Dun for kindly forwarding copies of their publications.

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CONFIRMATION OF *EUPLOEA LEUCOSTICTOS* (GMELIN) AND *E. NETSCHERI ERANA* (FRUHSTORFER) (LEPIDOPTERA: NYMPHALIDAE) IN TORRES STRAIT, QUEENSLAND, AND THE FIRST RECORD OF *E. TULLIOLUS DUDGEONIS* (GROSE-SMITH) IN AUSTRALIA

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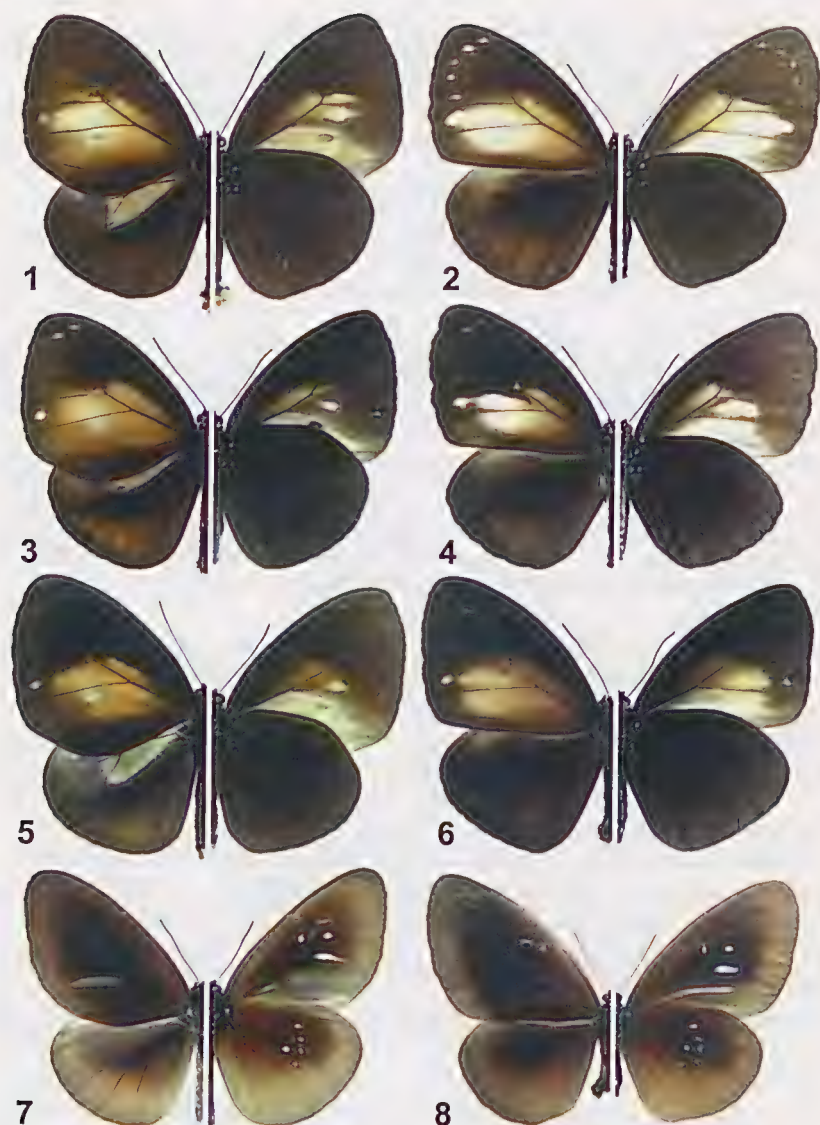
Abstract

Recent collections of *Euploea leucostictos* (Gmelin) and *E. netscheri erana* (Fruhstorfer) on Saibai and Dauan Islands confirm their establishment in Torres Strait, Queensland. *Euploea tulliolus dudgeonis* (Grose-Smith) is recorded in Australia for the first time from Dauan Island, and its relationship with *E. t. tulliolus* (Fabricius) is discussed. Up to date information on collections of the four taxa in Torres Strait is provided, including their variability and diagnostic facies, current distributions, seasonality, habits and prevalence. Evidence is provided suggesting that a sympatric zone exists for *E. t. tulliolus* and *E. t. dudgeonis* on Dauan and Yam Islands, with some intermediate specimens known from these and other Torres Strait islands. Confirmed Australian specimens of *E. leucostictos* and *E. tulliolus dudgeonis*, together with the male underside and female of *E. netscheri erana*, are illustrated for the first time.

Introduction

The greatest diversity of *Euploea* Fabricius occurs within the Indo-Australian region, with at least 54 species known (Corbet and Pendlebury 1978, Ackery and Vane-Wright 1984, Parsons 1998), especially on Java, Sumatra and in northern New Guinea (Scheermeyer 1999). Most *Euploea* species are medium-sized (forewing length *ca* 40 mm) and velvety-black or dark brown with some white markings, although the forewings of some species are adorned with blue hues overlying the white markings (D'Abrera 1978, Morishita 1985, Parsons 1998). Other species, such as *E. leucostictos* (Gmelin) (form *usipetes* Hewitson) and *E. wallacei* C. & R. Felder, are predominately orange and black (Parsons 1998), while some forms of *E. stephensii* C. & R. Felder are pearly white in colour (Morishita 1985). The majority of *Euploea* species are restricted to forest or heavy woodland habitats (Ackery and Vane-Wright 1984), but some occur in open woodland and urban areas, including coastal woods and mangroves (Braby 2000, Lambkin 2001).

On mainland Australia, diversity among *Euploea* is relatively poor, with only *E. core corinna* (W.S. Macleay) and, to a lesser extent, *E. tulliolus tulliolus* (Fabricius) being widely distributed. The three or four other mainland species [the placement of *E. eichhorni* Staudinger as a subspecies of *E. alcatheae* (Godart) is still conjectural (Lambkin 2001)] are restricted to tropical Australia (Scheermeyer 1999, Braby 2000). The diversity of *Euploea* increases just north of mainland Queensland, with 10 species known from Torres Strait (Braby 2000, Meyer *et al.* 2004). Of these 10, eight have been



Figs 1-8. *Euploea* spp. All figures to scale: upperside left, underside right [forewing lengths in parenthesis]. (1-6) *E. leucostictos*: (1, 3, 5) males: (1) Dauan I., 21.iv.2001 [40 mm]; (3) Dauan I., 29.xii.2005 [40 mm]; (5) Dauan I., 20.i.2004 [42 mm]; (2, 4, 6) females: (2) Dauan I., 19.ii.2004 [42 mm]; (4) Dauan I., 25.xii.2005 [41 mm]; (6) Dauan I., 17.xii.2005 [43 mm]. (7-8) *E. netscheri erana*: (7) male, Dauan I., 17.ii.2004 [40 mm]; (8) female, Dauan I., 5.i.2006 [42 mm].



Figs 9-16. *Euploea tulliolus*. All to scale: upperside left, underside right [forewing lengths in parenthesis]. (9-12) *E. t. dudgeonis*: (9) male, Subitana, PNG, 10.vii.1949 [35 mm]; (10) female, Subitana, PNG, xii.1949 [34 mm]; (11) male, Dauan I., 18.i.2004 [36 mm]; (12) female, Dauan I., 17.xii.2005 [35 mm]; (13-14) *E. t. dudgeonis/tulliolus* intermediates: (13) male, Yam I., 11-12.vi.1992 [34 mm]; (14) female, Thursday I., 12-15.iv.1992 [34 mm]; (15-16) *E. t. tulliolus*: (15) male, Murray I., 29.iii.-4.iv.1986 [34 mm]; (16) female, Murray I., 29.iii.-4.iv.1986 [36 mm].

recorded from Dauan Island (unpublished data), a small, volcanic island with large stands of vine thicket located just off the south-west tip of Saibai Island, close to the Papua New Guinea border. In general, the distribution and seasonality of *Euploea* species in Torres Strait are poorly documented; only Braby (2000) briefly summarised what was then known. In addition, the overall similarity between many *Euploea* species and a high degree of polymorphism has made their delimitation notoriously difficult (Ackery and Vane-Wright 1984). Furthermore, females of *Euploea* are often even more difficult to identify because of the similarity of many species, a problem compounded by the prevalence of mimicry complexes, the lack of secondary sexual characters, variable wing patterns (Ackery and Vane-Wright 1984, Parsons 1998), and what appear to be natural hybrids (De Baar 1991).

Of the 10 species recorded from Torres Strait, the majority are now well represented in many private collections. Despite this, three species are still known from very few specimens: a single male of *E. modesta* Butler was recently collected on Murray Island (Meyer *et al.* 2004); *E. leucostictos* (Gmelin) is currently known by only a handful of specimens (Waterhouse and Lyell 1914, Braby 2000); while *E. netscheri erana* (Fruhstorfer) is recorded from a single male collected on Dauan Island in May 1995 (Johnson and Valentine 1997). In addition, because of the paucity of collection records, it has been uncertain if these three species breed within Australian territory, or if the few specimens known to date are vagrants from Papua New Guinea.

In this paper, up to date information on collections of *E. leucostictos* and *E. netscheri erana* from Torres Strait is provided, including notes on their variability and diagnostic facies, their current distributions, seasonality, habits and prevalence. These recent records point towards both species being resident in Australia. In addition, *E. tulliolus dudgeonis* (Grose-Smith) is recognised in Australia for the first time, its relationship with *E. t. tulliolus* (Fabricius) is discussed and current data on their distribution, habits and seasonality in Torres Strait are reported.

Abbreviations of collections and their locations are: ANIC – Australian National Insect Collection, Canberra; CGMC – C.G. Miller collection, Lennox Head; JFDC – J.F. Donaldson collection, Thornlands; MDBC – M. De Baar collection, Brisbane; QM – Queensland Museum, Brisbane; QMTQ – Queensland Museum of Tropical Queensland, Townsville; PSVC – P.S. Valentine collection, Townsville; QDPIFC – Queensland Department of Primary Industries Collection, Brisbane; SSBC – S.S. Brown collection, Bowral; TLIKC – joint collection of T.A. Lambkin and A.I. Knight, Brisbane. Abbreviations of collectors are: AIK – A.I. Knight; CGM – C.G. Miller; EH – E. Hamacek; EJJLH – E.J.L. Hallstrom; IFTA – Insect Farming and Trading Agency; JA – J. Andrews; JFD – J.F. Donaldson; MDB – M. De Baar; NG – N. Gough; PSV – P.S. Valentine; SJJ – S.J. Johnson; SSB – S.S. Brown; TAL – T.A. Lambkin; WWB – W.W. Brandt.

E. leucostictos (Gmelin)

(Figs 1-6)

Material examined. QUEENSLAND: 1 ♂, Cape York [ex Miskin Collection] (QM); 1 ♀, Thursday Island, Torres Strait [ex Illidge Collection] (illustrated in Tindale 1923); 1 ♀, Saibai Island, Torres Strait, 25.xii.1980, JA (PSVC); 7 ♂♂, 5 ♀♀, Dauan Island, Torres Strait, 21.iv.2001 (♂), 18.i.2004 (♀), 20.i.2004 (♂), 24.i.2004 (♀), 25.i.2004 (♂), 16.xii.2005 (♂), 17.xii.2005 (♀), 23.xii.2005 (♂, 2 ♀♀), 25.xii.2005 (♂), 29.xii.2005 (♂), AIK (TLIKC); 1 ♂, same data except 22.iv.2001, AIK (ANIC); 1 ♂, same data except 24-30.i.2004, AIK (SSBC); 1 ♀, same data except 3.iv.2004, PSV (PSVC); 1 ♂, 1 ♀, same data except 5.iii.2005 (♂), 6.iii.2005 (♀), SJJ (QMTQ); 1 ♀, same data except 13-19.iv.2001, SSB (SSBC); 1 ♂, 1 ♀, same data except 19.ii.2004 (♀), 6.i.2006 (♂), TAL (TLIKC); 2 ♂♂, Murray Island, Torres Strait, 9.iii.1995, TAL (TLIKC). PAPUA NEW GUINEA: 3 ♂♂, 1 ♀, Kiunga, Fly River, 2.vii.-31.x.1957, WWB (ANIC); 1 ♂, Rouku, Morehead River, 1962 (MDBC).

Discussion. *Euploea leucostictos* is a wide-ranging species, occurring from the Taluad Archipelago and Buru through the Moluccas, New Guinea, the Bismarck Archipelago and the Solomon Islands, to Vanuatu (New Hebrides), New Caledonia and Fiji (Ackery and Vane-Wright 1984, Parsons 1998). It is widespread throughout Papua New Guinea, extending south to Western Province and into Torres Strait. Parsons (1998) reported that it is 'occasional generally' and is most often associated with marginal secondary forest up to 1200 m. Prior to Parsons (1991), the taxonomic placement of many of the forms of *E. leucostictos* in New Guinea was unclear, as the species is locally and regionally highly variable and is thought to form part of two or three Müllerian mimicry complexes, including an association with an orange *Euploea* species, *E. wallacei*, throughout mainland Papua New Guinea (Parsons 1998). For convenience, Parsons (1998) provisionally named these different phenotypes as forms of *E. leucostictos*, although the only form occurring in the part of Western Province bordering Torres Strait is the orange form 'usipetes' (Parsons 1998, ANIC Brandt collection, as illustrated in Braby 2000).

The first specimens of *E. leucostictos* known from northern Australia, and being the only specimens known for the better part of a century, were a male from Cape York and a female from Thursday Island in Torres Strait (Waterhouse and Lyell 1914). The male, in the Queensland Museum (QM) and described as *E. hippias* Miskin by Miskin (1890), formed part of Miskin's collection, which included a number of other *Euploea* types described at the same time (Miskin 1890). Subsequently, Waterhouse and Lyell (1914), illustrated Miskin's type, recognised *E. hippias* as a junior synonym of *E. usipetes* Hewitson and nominated *E. u. hippias* as the Australian subspecies. A review of Miskin's *Euploea* types in the QM has indicated that most specimens have almost no label data, apart from collection locations, except the type of *E. amycus* Miskin, which has reference to a date, 'F.M. -/5/75'. This date might also refer to the collection

time of Miskin's Cape York specimen of *E. leucostictos*. During the latter part of the 19th century, numerous natural history collections were made at Cape York (Lambkin 2005, Olliff 1891), but some doubt exists concerning the veracity of some of these collection records, as Cape York and Thursday Island were common ports of call en route to and from Aru and New Guinea (Whittell 1954, Monteith 1987, Lambkin 2005). Considering that Miskin's specimen of *E. leucostictos* (*E. hippias*) is still the only specimen known from the Australian mainland, there is still some doubt as to the true origin of Miskin's type. Equally, very little is known of the female specimen from Thursday Island except that it was originally in the collection of R. Illidge, before passing to the T.P. Lucas collection, and eventually was acquired by the South Australian Museum (illustrated in Tindale 1923). Additionally, as no further specimens are known from Thursday Island, the veracity of the female specimen's stated locality might also be questionable.

These two *E. leucostictos* specimens remained the only known Australian examples until 1980, when a female was collected on Saibai Island in December, by J. Andrews from James Cook University, Townsville (PSVC). With a general increase in collecting in Torres Strait during the 1990s (Lambkin and Knight 2005), two further males were collected on Murray Island (TLIKC), and an additional 20 specimens have been accumulated from Dauan Island since 2001. Apart from the single female collected on Saibai, which is predominately a mangrove island, the remaining specimens have all been collected on Murray and Dauan Islands, which are largely covered with monsoon vine thicket. Despite all known specimens being of form 'usipetes', some variation occurs in both sexes in the extent of the forewing orange area and the size of the white patch enclosed in this area (Figs 1-6). Variation also occurs in the presence and number of the forewing upper and underside subapical white spots, and in the size of the single white spot occurring in the subterminal area of the forewing upperside (Figs 1-6). These characters are also variable in specimens from southern Papua New Guinea (ANIC).

The males from Murray Island, and the majority of specimens known from Dauan Island, were collected roosting or congregating with other *Euploea* spp. (Braby 2000) in the afternoon, under or near large flowering trees of *Terminalia* spp. and mangroves. In addition, a number of specimens have been netted from *Melaleuca* blossom in the early morning. In Torres Strait, label data from the known specimens of *E. leucostictos* indicate that it has two generations annually, with the majority of specimens collected at the start of the wet season in December and January (14 specimens) and then again in March and April (8 specimens), with only a single male known from February. Almost all known specimens collected from Torres Strait are in good condition, indicating that they were unlikely to be vagrants but were probably established. Therefore, collection data indicates that in Torres Strait, the species is restricted to Dauan, with the probability of a remote population

occurring on or near Murray, as Murray represents a close group of three islands: Mer (Murray), Dauar and Waiar.

***Euploea netscheri erana* (Fruhstorfer)**

(Figs 7-8)

Material examined. QUEENSLAND: 1 ♂, Dauan Island, Torres Strait, 2-5.v.1995, SJJ (QMTQ); 1 ♂, 2 ♀♀, same data except 17.ii.2004 (♂), 5.i.2006 (♀), 6.i.2006 (♀), TAL (TLIKC); 1 ♀, Saibai Island, Torres Strait, 13.ii.2004, AIK (TLIKC).

Discussion. *Euploea netscheri* Snellen is a localised lowland species (Ackery and Vane-Wright 1984, Parsons 1998) that occurs on Gebe, Seram, Misool, Salawati, Waigeo, Japen and eastwards throughout mainland New Guinea (Ackery and Vane-Wright 1984, Parsons 1998). In Papua New Guinea, only *E. n. erana* occurs. It is a distinctive subspecies, typically distinguished by its broad, pale wing margins which contrast strikingly with the very dark brown ground colour of the wings. The male has a prominent sex-brand distinctively placed in the subterminal area of the forewing upperside below vein CuA₂ (Fig. 7). In Australia, the species was previously known only from a male collected on Dauan Island, Torres Strait in May 1995 (Johnson and Valentine 1997). Since 2004, three more specimens have been collected on Dauan (1 male, 2 females) and another female has been collected on nearby Saibai. The external facies of all known specimens are consistent with the male illustrated by Johnson and Valentine (1997) and the male and female illustrated here (Figs 7-8).

The male and female specimens collected in 2004 were flying in sparse vine thicket bordering mangroves, while the two females netted more recently (in 2006) were roosting under a flowering *Terminalia* sp. All females flew in a relatively lazy manner and were easily netted, while the male flew briskly about a metre above the ground. It is remarkable that, despite intensive collecting of *Euploea* spp. on Dauan and Saibai since 2001, only four specimens of this species have been collected.

***E. tulliolus dudgeonis* (Grose-Smith)**

(Figs 9-12)

Material examined. QUEENSLAND: 12 ♂♂, 9 ♀♀, Dauan Island, Torres Strait, 25.iv.2000 (♀), 8.v.2000 (♂), 18.v.2000 (♂), 3.iv.2001 (♂), 4.iv.2001 (♀), 20.iv.2001 (♂), 16.i.2004 (♂), 18.i.2004 (4 ♂♂, 2 ♀♀), 17.xii.2005 (♂, 2 ♀♀), 19.xii.2005 (♀), 23.xii.2005 (♂), 25.xii.2005 (2 ♀♀), 29.xii.2005 (♂), AIK (TLIKC); 1 ♂, same data except 11.v.2001 (ANIC); 3 ♂♂, 1 ♀, same data except 18.ii.2004 (3 ♂♂), 10.i.2006 (♀), TAL (TLIKC); 1 ♂, Saibai Island, Torres Strait, 15.v.2001, AIK (TLIKC); 1 ♂, 1 ♀, Yam Island, Torres Strait, 11-12.vi.1992, AIK (JFDC). PAPUA NEW GUINEA: 1 ♂, Subitana (Central District), 1800 ft, 10.vii.1949, WWB & EJLH (ANIC); 1 ♂, same data except 12.x.1949; 1 ♀, same data except xii.1949; 7 ♂♂, Sambio, Mumeng, Morobe Province, xii.1984 (2 ♂♂), i.1985 (5 ♂♂), IFTA (TLIKC); 2 ♂♂, Bulolo, Morobe Province, i.1985, IFTA (TLIKC).

E. tulliolus dudgeonis/tulliolus intermediates

(Figs 13-14)

Material examined. QUEENSLAND: 5 ♂♂, 6 ♀♀, Dauan Island, Torres Strait, 31.iii.2001 (♂), 16.i.2004 (♀), 18.i.2004 (♂, ♀), 24.i.2004 (♂, ♀), 17.xii.2005 (2 ♂♂), 25.xii.2005 (2 ♀♀), 4.ii.2006 (♀), AIK (TLIKC); 1 ♂, Yam Island, Torres Strait, 20.vii.1977, CGM (CGMC); 1 ♂, same data except 11-12.vi.1992, AIK (TLIKC); 2 ♀♀, same data except 11-12.vi.1992, AIK (JFDC); 1 ♀, Green Hill, Thursday Island, Torres Strait, 12-15.iv.1992, TAL (TLIKC); 1 ♂, Campbell Island, Torres Strait, 3.iv.1987, MDB (MDBC).

***E. tulliolus tulliolus* (Fabricius)**

(Figs 15-16)

Material examined. QUEENSLAND: 2 ♂♂, 2 ♀♀, Dauan Island, Torres Strait, 20.iv.2001 (♀), 21.iv.2001 (♂), 25.xii.2005 (♂), 7.ii.2006 (♀), AIK (TLIKC); 1 ♂, Murray Island, Torres Strait, 2.v.1984, NG (QDPIFC); 2 ♀♀, same data except 29.v.-3.vi.1985, JFD & EH (QDPIFC); 3 ♂♂, 3 ♀♀, same data except 29.iii.-4.iv.1986, MDB (MDBC); 4 ♀♀, same data except TAL (JFDC); 4 ♂♂, 3 ♀♀, same data except TAL (TLIKC); 1 ♂, 1 ♀, same data except TAL (QDPIFC); 6 ♂♂, 1 ♀, same data except 30.iii.1990, JFD (JFDC); 2 ♂♂, 1 ♀, same data except 13.i.1994, TAL (TLIKC); 1 ♂, 3 ♀♀, same data except 14.i.1994 (♂), 15.i.1994 (2 ♀♀), 14.v.1994 (♀) TAL (JFDC); 1 ♂, same data except 7.iv.2001, SSB (TLIKC); 5 ♂♂, Darnley Island, Torres Strait, 1-2.iv.1987, MDB (MDBC); 1 ♂, Thursday Island, Torres Strait, 27-30.iii.1987, MDB (MDBC); 1 ♂, 1 ♀, Campbell Island, Torres Strait, 3.iv.1987, MDB (MDBC); 1 ♂, Yam Island, Torres Strait, 24.iii.1994, TAL (JFDC); 1 ♂, Jara Ck., W. of Tully, 13.v.1979, TAL (QDPIFC); 2 ♂♂, Flying Fish Pt., 14.v.1979, TAL (QDPIFC); 1 ♀, Mackay, 18.v.1971, JFD (JFDC); 2 ♂♂, 1 ♀, Yeppoon, 1.v.1985 (♂), 10.v.1987 (♂), 24-30.vi.1990 (♀), AIK (TLIKC); 1 ♂, 1 ♀, 3 km E of Palmwoods, 22.ii.1978, JFD (JFDC); 1 ♂, Maleny, 24.ii.1974, TAL (QDPIFC); 2 ♂♂, 1 ♀, same data except 9.iii.1975; 1 ♀, same data except 25.i.1976; 4 ♂♂, 1 ♀, Mt. Beerburum, 29.i.1977, TAL (QDPIFC); 1 ♂, Currumbin, 2.iii.1980, TAL (TLIKC). NEW SOUTH WALES: 1 ♂, Victoria Pk., 7.ii.1974, TAL (QDPIFC).

Discussion. *Euploea tulliolus* is widespread from Taiwan and southern China, through the Malay Peninsula, the Philippines, Sumatra, Borneo, Java, Sumba, Sumbawa, Flores and New Guinea, eastwards to Vanuatu and Fiji and south to northeastern Australia (Ackery and Vane-Wright 1984, Parsons 1998). It is absent from Timor, Sulawesi and the eastern Lesser Sunda Islands (M. De Baar, unpublished data). Closer to Australia, *E. t. dudgeonis* occurs throughout mainland Papua New Guinea (Parsons 1998), while the nominate race, *E. t. tulliolus*, is restricted to Australia, occurring in Torres Strait, throughout Cape York Peninsula and coastal Queensland, to northern New South Wales (Braby 2000). *Euploea t. dudgeonis* differs from *E. t. tulliolus* in possessing much smaller forewing subapical and subterminal white markings on both upper and undersides, a more intense blue sheen on the forewing upperside, and vibrant blue patches overlying these upperside white markings (Figs 9-10) (Parsons 1998, ANIC). The difference between the sizes of the forewing white markings of both taxa is particularly diagnostic when viewed

from the underside; the white markings of *E. t. dudgeonis* appear as spots or dots, while in *E. t. tulliolus* they are prominent bars, particularly in the spaces above veins M_1 and M_2 (Figs 9-16). Within Papua New Guinea, *E. t. dudgeonis* is a variable taxon, with specimens from Morobe Province (Bulolo and Sambio) having the white forewing markings reduced markedly to white dots, while a male illustrated by Parsons (1998), and specimens examined (ANIC) from Subitana in Central Province, very closely resemble individuals from Dauan and Yam Islands (Figs 9-12). Despite the variability of *E. t. dudgeonis*, it always has the blue sheen on the upperside of the forewing but never has the distinctive long, subapical white bars that *E. t. tulliolus* consistently has (44 males and 26 females examined; Braby 2000).

In Torres Strait, collection records indicate that the species has a patchy distribution (Lambkin and Knight 2005), likely related to the distribution of the larval host plant, *Trophis scandens* (Lour.) Hook. & Arn. (Moraceae). Lambkin and Knight (2005) discussed the distribution of *E. tulliolus* in Torres Strait and concluded that it was confined to islands with stands of beach or monsoon forest, and was known from the following islands: in the east of the strait (Murray, Darnley, Campbell and Dalrymple [just west of Campbell]), in the centre (Moa, Sue and Yam), in the south from Thursday Island, and from Dauan Island in the north (Fig. 17). Until now, all Torres Strait material was believed to be *E. t. tulliolus*. However, an examination of material from Campbell, Darnley, Dauan, Murray, Saibai, Thursday and Yam Islands has shown that many specimens from Dauan (26 of 45) (Figs 11-12), two of seven known from Yam, and a male from Saibai were identical to *E. t. dudgeonis* from Papua New Guinea, particularly those from Central Province (ANIC) (Parsons 1998) (Figs 9-10). Almost all specimens examined from other Torres Strait islands were typical *E. t. tulliolus* (Figs 15-16), with a number of intermediate forms recorded, predominately from Dauan and Yam (Fig. 13), but also from Campbell and Thursday Islands (Fig. 14).

Ackery and Vane-Wright (1984) alluded to the taxonomic problems that occur with the various 'races' of *E. tulliolus*. They based this view primarily on ecological data observed in several countries throughout its range, and concluded that the taxon probably represents a group of sibling species. In support of this premise, *E. t. dudgeonis* from Dauan and Yam Islands has a distinct seasonality that is somewhat different from that of *E. t. tulliolus* recorded from other Torres Strait islands (Braby 2000). On other islands in Torres Strait where the species occurs, it is generally widespread and common, and is observed throughout the year (unpublished records, Waterhouse and Lyell 1914, De Baar 1988, Lambkin and Knight 1990). Conversely, on Dauan Island, where one of us (AIK) has collected intensively over the period from December to May (with other unpublished records from November), and on Yam (unpublished collection records from March, April, June and July), collection records indicate that *E. t. dudgeonis* is generally rare but may be occasional locally with flight mostly restricted to

two main periods (Fig. 18). Most specimens recorded are from a first 'brood' that occurs at the onset of the wet season in December and January, while a second 'brood' principally occurs in April and May. On Dauan, both sexes of *E. t. dudgeonis* fly in vine thicket margins, where they visit blossom of *Melaleuca*, *Terminalia* and mangrove species, and roost or congregate with other *Euploea* spp under *Terminalia* spp, mangroves and in bamboo thickets.

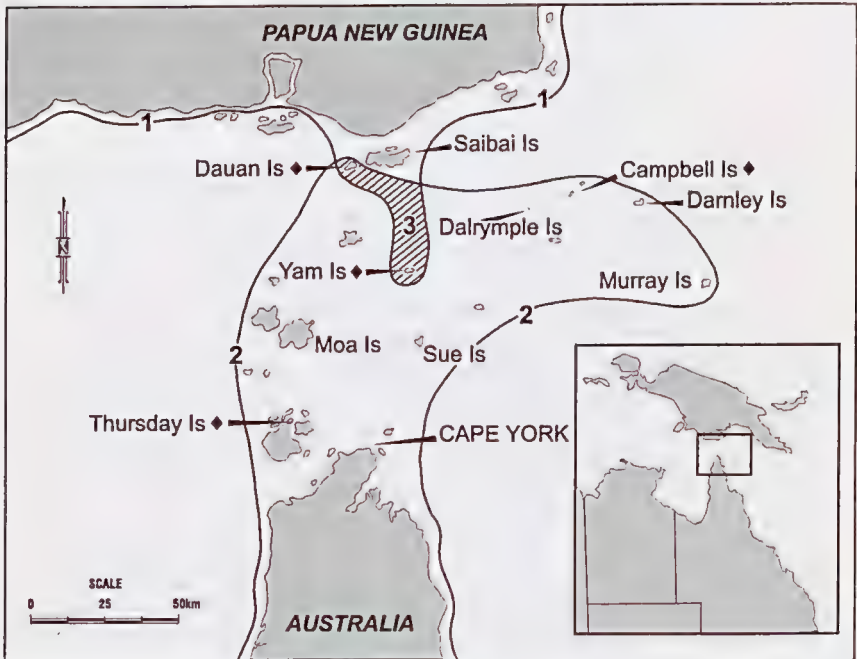


Fig. 17. Torres Strait, Queensland: recorded distribution of *Euploea tulliolus dudgeonis* (1), *E. t. tulliolus* (2) and sympatric zone (3), with locations of some known intermediate specimens indicated with ♦.

The two taxa, currently classified as subspecies, might well be separate species forming a hybrid zone in Torres Strait, as is the suspicion for other *Euploea* spp. (De Baar 1991). This is further evidence in support of Ackery and Vane-Wright's (1984) sibling species supposition. Nonetheless, this current study indicates that *E. t. dudgeonis* occurs exclusively in Papua New Guinea and, in Australia, on Dauan and Yam Islands in Torres Strait. Moreover, typical *E. t. tulliolus* occurs solely in eastern Australia and Torres Strait, where it is recorded infrequently in the north of the strait. Thus, a sympatric zone occurs on Dauan and Yam, with intermediates found predominately on these two islands and, occasionally, on other islands such as Campbell and Thursday (Fig. 17).

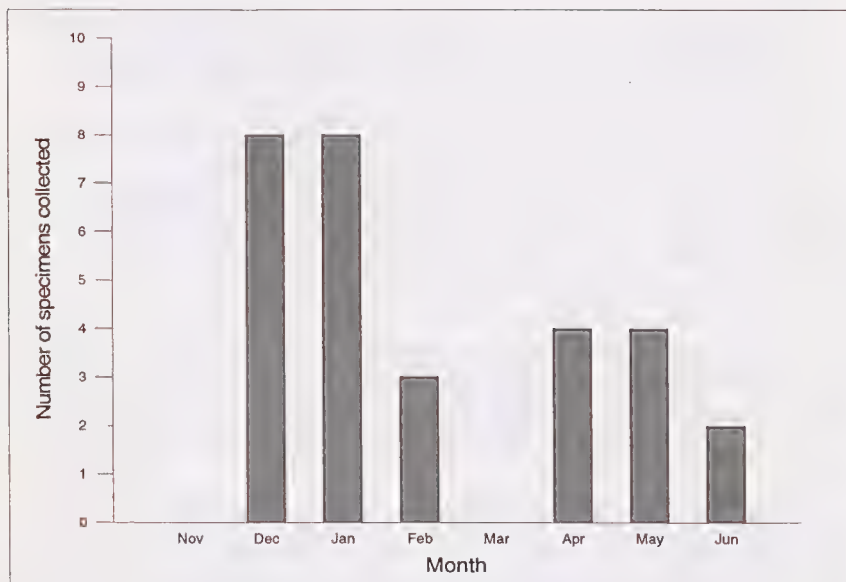


Fig. 18. Seasonality of *Euploea tulliolus dudgeonis* in Torres Strait, Queensland (Dauan, Saibai and Yam Islands): data based on November to June collection records (n = 29).

Acknowledgements

We thank the local community councils of Saibai and Dauan Islands for permitting field collections. Appreciation is given to S.S. Brown, M. De Baar, J.F. Donaldson (including QDPIFC, Brisbane), E.D. Edwards (ANIC, Canberra), S.J. Johnson (QMTQ, Townsville), C.G. Miller, G. Thompson (QM, Brisbane) and P.S. Valentine for access to specimens held in their collections. J.S. Bartlett gave valuable support by formatting and preparing the map and colour plates.

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LEG AUTOTOMY AND REGENERATION IN A POPULATION OF *DIDYMURIA VIOLESCENS* (LEACH) (PHASMATODEA: PHASMATIDAE) IN NEW SOUTH WALES, AUSTRALIA

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Abstract

A population of the spurlegged phasmid, *Didymuria violescens* (Leach), was surveyed in New South Wales, Australia, in order to determine rates of leg autotomy and regeneration in natural environments. Autotomy was common during all instars, and rates of regeneration ranged from ~10% in nymphs to ~25% in adults. Autotomy and/or regeneration also appeared to negatively affect survivorship.

Introduction

All phasmids have the ability to shed and regenerate legs (Bordage 1905, Ramme 1931, Carlberg 1986, Brock 1999). There are two advantages in shedding legs (autotomy): predation avoidance and moulting. If a predator grabs a leg instead of the body, the animal can shed the leg and survive. In addition, legs can be lost to a fouled moult. Phasmids moult upside down and separate themselves from their old exoskeleton with elaborate twisting and turning manoeuvres. During moulting, the long, thin legs, so effective at conferring crypsis, can become entangled in the old cuticle and must be shed to survive.

Complete replacement of a lost leg requires three consecutive instars, each moult producing a successively larger leg. The first moult after leg loss produces a leg about one-quarter the normal size, the second moult produces a leg about half the normal size, and the third moult produces a leg that is ~10% smaller than a non-regenerated leg (see Figure 1). Regenerated legs never attain their full proportions, even with several moults remaining in their life cycle (Ramme 1931, Carlberg 1986, 1992, T. Maginnis personal observation). Hatchlings which lose a leg during the first instar do not produce regenerated legs until the third instar and, with the exception of the instar before maturity, nymphs always commence the regeneration process (T. Maginnis personal observation).

As in many other species with regenerative capacities, little is known about how often phasmids lose and regenerate legs in natural environments. *Didymuria violescens* (Leach), the spurlegged phasmid, is an ideal species to explore this because it is a forest pest in many higher elevation areas of Victoria and New South Wales (Campbell and Hadlington 1967, Neuman *et al.* 1977, Schoenborn *et al.* 2003), and large samples are easily collected.

The goals of this field study were: (i), to sample a population from hatching to maturity to determine rates of autotomy and regeneration, and (ii), to explore if autotomy/regeneration affected survivorship.

Methods

An outbreak population of *D. violescens* was located in Bago State Forest, New South Wales, on 19 November, 2003 and studied until 6 February, 2004 (insects hatched in November and took ~3 months to mature). A survey of the area determined the outbreak to be approximately 50 m x 120 m (while some individuals were found outside this area, the majority of individuals were found within it). Within the 50 x 120 m plot, we set up 5 transects, each 120 m long and 8 m apart. Nymphs were collected along each transect. Each individual was measured for body length, examined for missing and/or regenerated legs, and released where it was collected. The measurements were used to ascribe each specimen to instar using the data of Neuman (1974) as follows: instar 1 = 1.80 cm (S.E. \pm 0.5 cm), instar 2 = 2.88 cm (S.E. \pm 0.5 cm), instar 3 = 3.89 cm (S.E. \pm 0.6 cm), instar 4 = 5.74 cm (S.E. \pm 0.8 cm), instar 5 = 7.67 cm (S.E. \pm 0.8 cm), adult/instar 6 = 8.68 cm (S.E. \pm 0.8 cm). Since the sexes are not distinguishable until the 3rd instar, rates of autotomy and regeneration for males and females were combined until maturity. After all transects were completed (approximately 10 days), we did not re-sample the area for another 5-10 days. This waiting period was sufficient to allow moulting to the next instar and minimized the likelihood of measuring the same individual in the same instar twice. The population was sampled during all instars except the fifth; these individuals can have completely regenerated legs that are only slightly shorter than non-regenerated legs, precluding scoring of regenerated legs in the field.

In addition to the data collected on the instar 1-4 nymphs, 803 adults (411 males, 392 females) were collected and brought back to the laboratory. We measured their body length and all six leg lengths. Because regenerated legs are always smaller than non-regenerated legs, paired t-tests between opposite legs (e.g. both front legs, both middle legs, and both hind legs) were used to identify regenerated legs.

To test if autotomy/regeneration affected survivorship, two 'expected' rates of regeneration were calculated. First, we calculated the minimum 'expected' rate of leg regeneration in adults by summing the rates of autotomy we observed in instars 2-4, since these individuals presumably commenced the regeneration process. Rates of autotomy for instar 1 individuals were not included in this 'expected rate' because they do not commence regeneration until instar 3; our proportion of instar 2 individuals missing one leg (13.2%) likely included many of the instar 1 individuals missing one leg (7.7%). Thus, if losing a leg had little or no effect on survival we expected at least 34.0% of sampled adults to have a partially or completely regenerated leg based on the observed rates of autotomy in instars 2-4 (13.2% instar 2 + 11.2% instar 3 +

9.6% instar 4 = 34.0%, see Table 1). Second, we calculated a minimum 'expected' rate of completely regenerated legs in adults by summing the rates of partially regenerated legs in instars 3 and 4, again because these individuals presumably completed the regeneration process ($10.2\% + 8.7\% + 3.2\% = 22.1\%$, see Table 1). Thus, if regenerating a leg has little or no effect on survival we expected to see at least 22.1% of sampled adults with completely regenerated legs. Although we did not sample instar 5, individuals that lose a leg at this instar do not regenerate it, and would therefore not contribute to the overall rates of partially or completely regenerated legs in adults.

Results and discussion

Didymuria violescens lost legs during all stages of development (Table 1). In each nymphal instar, approximately 10% of the individuals were missing one leg. A relatively high proportion of adults (15.3%) showed evidence of new leg losses, but this figure represents new losses during both instar 5 and adults. Approximately 25% of all sampled adults regenerated at least one leg during development (24.2% of males [$n = 411$]; 25.6% of females [$n = 392$]). 5.7% of adults had two regenerated legs and 3.2% had three or more ($n = 803$).

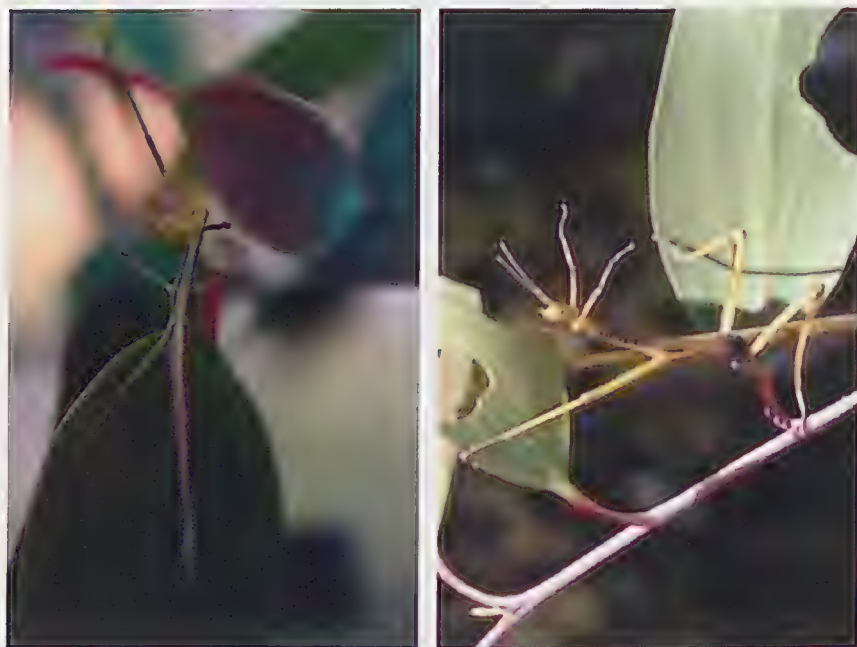
Autotomy and/or regeneration appeared to have negatively affected survivorship. Based on how often nymphs lose legs, we expected to see at least 34% of the adults in this population with evidence of regeneration but sampling revealed only 25.2% (9.4% of adults with partially regenerated legs + 14.8% of adults with completely regenerated legs). This pattern persisted when we used partial leg regeneration instead of autotomy to predict regeneration rates in adults. Based on the proportion of individuals with partially regenerated legs in instars 3 and 4, we expected to see at least 22.1% of adults with completely regenerated legs but sampling revealed 14.8%. Although we did not have data on the proportion of instar 5 individuals with partially or completely regenerated legs, it is likely the decreased survivorship patterns would persist and/or be strengthened by these data.

In addition, progression through instars generally showed a drop of a few percent in sequential regeneration. For example, 13.2% of instar 2 individuals were missing a leg and only 10.2% of instar 3 individuals had a first stage regenerated leg. Similarly, 11.2% of instar 3 individuals were missing a leg and only 8.7% of instar 4 individuals had a first stage regenerated leg. It is also noteworthy that only 3.2% of instar 4 individuals had a second stage regenerated leg, while 10.2% of instar 3 individuals had a first stage regenerated leg. This might suggest: (i), a sampling error or (ii), a disproportionately severe survivorship effect on instar 3 individuals with a first stage regenerated leg in this population.

All these patterns suggest decreased survivorship in individuals that are missing and/or in the process of regenerating legs. They are consistent with

Table 1. Frequencies of leg autotomy and regeneration in a population of *Didymuria violescens*.

Instar	Number (N)	% of N missing one leg	% of N in first stage of regeneration	% of N in second stage of regeneration	% of N with completely regenerated legs
1	482	7.7	-	-	-
2	502	13.2	-	-	-
3	509	11.2	10.2	-	-
4	519	9.6	8.7	3.2	-
5	Not sampled				
Adult	803	15.3	-	9.4	14.8

**Fig. 1.** Regenerated legs in *Didymuria violescens*: (left) an individual with a front right leg in the first stage of regeneration; (right) an individual with both front legs in the second stage of regeneration.

studies on crabs (Decapoda: Brachyura) that revealed a low percentage of adults with regenerated appendages compared with the high proportion of non-adults that were missing appendages (Savage *et al.* 1975, McVean and Findlay 1979, Lysenko *et al.* 2000). A mark-recapture study would further test the effects of autotomy and/or regeneration on survivorship.

Conclusion

Sampling *D. violescens* during their development revealed patterns about how often legs are autotomised and regenerated, as well as insight into its effects on survivorship. Recognizing that leg autotomy and regeneration occurred in approximately 25% of individuals in this population suggests that factors affecting autotomy and regeneration may be important agents of selection. More field research into other species will reveal if the rates of autotomy and/or regeneration in *D. violescens* are typical of other phasmids.

Acknowledgements

We thank Nick Collett (Melbourne University) and Peter Haenig (State Forests of New South Wales) for their assistance before, during and after this field study. We also thank two anonymous reviewers for helpful comments on the manuscript and Doug Emlen for his ideas and support. This research was funded by the National Science Foundation (# 0309038), Sigma Xi, and The University of Montana. We dedicate this project to the memory of Alex Marshall of Tumbarumba, NSW, our field assistant and truly altruistic young man.

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THE AUSTRALIAN
Entomologist

Volume 34, Part 1, 1 March 2007



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